DOCUMENT RESUME

ED 169 922 IR 007 209

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TITLE Costs and Effectiveness of Technological Applications in Education: A Literature Review.
INSTITUTION Florida State Univ., Tallahassee. Center for Educational Development and Evaluation.
SPONS AGENCY Florida State Board of Regents, Tallahassee.
BUREAU NO STAR-76-2061
PUB DATE Jan 77
NOTE 90p.; Florida School Finance Study; For related documents, see IR 007 209-211

EDRS PRICE MF01/PC04 Plus Postage.
DESCRIPTORS Computer Assisted Instruction; *Cost Effectiveness; *Educational Development; Educational Radio; *Educational Technology; Educational Television; *Instructional Design; *Intermode Differences; Program Costs; Programed Instruction; Systems Approach

ABSTRACT

This study exploring ways in which educational technology might be used to provide better schools for less money focuses on technological applications utilizing instructional radio, instructional television, computer-assisted instruction, computer-managed instruction, and programmed instruction. Based on a review of the literature on the costs and effectiveness of technological applications in education, it was concluded that technological applications (as hard technology) provide useful alternatives to "teacher delivered" instruction, but there is little or no evidence that such alternatives can greatly reduce costs in and of themselves. Present findings suggest that technological applications such as computers and television are solutions to only a limited set of problems. Educational technology (as soft technology) as a problem solving and planning process appears to hold more potential for achieving better schools for less money. This is the first in a series of three reports; the second and third present "future" scenarios on cost reduction for grades K-12, and in higher education. (Author/RAO)

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Costs and Effectiveness of Technological Applications in Education:

A Literature Review

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STAR Project
No. 76-2061

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Systems
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January, 1977

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ACKNOWLEDGMENTS

This research was supported by funds provided by the Board of Regents of the State University System of Florida under its Service Through Applications of Research (STAR) program. The work was done in collaboration with K. Fred Daniel and Martha Chang of the Florida Department of Education. We are grateful for their involvement and guidance.

We also wish to express our appreciation to the following individuals for their contributions in reviewing the literature and in preparing portions of the report itself. They include: Pamela Eaddy, Ethlyn Garlichs, Cynthia Hoffman, and Clementina Rodriguez. We are also appreciative of critical comments offered by Howard Tuckman. And finally, we express gratitude for the efficient and effective work of Bob Childress in typing the numerous draft copies and to Nancy Trela for documenting the search and for assembling the final report.

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COSTS AND EFFECTIVENESS OF TECHNOLOGICAL APPLICATIONS IN EDUCATION: A LITERATURE REVIEW

Introduction

Forecasts show that public education costs in Florida will increase much more rapidly than projected revenues (State of Florida Department of of Education, 1976). Factors contributing to this situation include inflation, an increase in the number of programs being offered to learners, and unionization and the impact which it is likely to have on increasing expenditures for teachers' salaries. Many taxpayers and legislators are concerned because they tend to see costs going up and educational quality going down. While this might not be true in all cases, it is true of people's perceptions.

It seems clear that the increases in the cost of education will not be a short term phenomenon. If present trends continue, the Baumol "Crunch" will become even more severe for education. Professor Baumol, an economics professor at Princeton University, has argued that there is a limit to the tolerance of the more productive segments of society toward those that are less productive. Baumol's "Crunch" occurs when the cost of doing business goes up and productivity of a given institution stays the same. Although this has always tended to be true, relatively recent increases in productivity in business and industry have thrust education into the spotlight. While Baumol's argument was directed at public agencies in general, the present financial crisis and pressures for accountability in the schools are manifestations of his hypothesis at work. Thus the only alternatives under present circumstances are for the schools to charge more for services (in the form of increased

taxes) or to seek other sources of funding. But can charging more for services be avoided without affecting quality? Many would argue that the solution lies in the application of technology.

The purpose of this report is to present the results of a review of the literature dealing with the costs and effectiveness of technological applications in education. The basic questions guiding our review were: Has modern technology yet reached the stage where it can be used to save a significant part of the costs of education--say 20%--without decreasing the quality of learning outcomes? If so, what are the most promising applications of technology for achieving these savings?

This report has been written with policy planners and policy makers in mind. The literature reviewed makes clear that the adoption of technological applications is a complex process with ramifications for all educational partners involved. Decisions to adopt a technological application to reduce educational costs will have far reaching impacts on: the way instruction is offered to learners; the way in which learning activities are organized and managed; the size of teacher/pupil ratios (and therefore the substance of collective bargaining agreements); curriculum diversity; and in other ways that can not be anticipated at the present time. The latter point should be emphasized because, as students of the history of technology have pointed out, it is not possible to foresee all consequences that will eventually evolve from the application of a specific technology. Environmental pollution brought on by industrial technology, which has led to breakdown of natural ecosystems and created lethal health hazards for animal and human species, is a frequently cited example of unanticipated consequences.

Specific audiences for this report therefore include policy planners in the Florida Department of Education and the Florida State Legislature, members of school boards, and chief administrators of school districts and other large educational institutions such as colleges and universities.

One other comment is in order. And that is that this report also intends to distinguish between:

- Technology as a process for identifying and resolving problems . . . and . . .
- Technological applications as the means by which problem resolution occurs

We feel that this distinction is a critical one because the potential for and magnitude of cost savings may well depend on how skillfully we employ the skills and processes involved in each--but more on this point later.

Scope of the Literature Review. The goal of this study has been to prepare a report on the state of the art of technological applications in education. At the outset we identified over a dozen different applications of educational technology ranging from hardware-based delivery systems such as the computer to integrative combinations of various applications such as competency-based education, multimedia instructional systems, needs assessment and so forth. As we reviewed the literature it became rapidly apparent that: (1) not all technological applications are well documented regarding costs and effectiveness; and (2) some applications possess a greater potential for cost reduction than others. In light of these observations, it was decided to place emphasis on technological applications utilizing:

- Instructional radio
- Instructional television
- Computer-assisted instruction
- Computer-managed instruction
- Programmed instruction

Before proceeding to examine the results of the literature review, it is important to examine the nature of educational technology so that its critical attributes can be identified and careful distinctions made between technology as a problem solving and design process and technological applications such as computers and instructional television.

1. The Nature of Educational Technology

In the United States, Technology is both a magical and a threatening word. It gave us mass-produced automobiles; it took us to the moon, and now to Mars. Many people believe that technology can make us successful beyond our wildest dreams. Still others warn us that technology will dehumanize if not destroy us. While there is no real magic in technology, it may offer us some ways and means for delivering educational change for less money and with greater effectiveness. Although we know much about how to design the required "miracle"--greater effectiveness at less cost--there are political and cultural problems which can not be designed away and are difficult to overcome.

One problem is the "scariness" of computers and other hardware-based technological applications because they supposedly lack the "human" element. Another is the resistance to change which plagues most people when anything new or different is considered. Still another problem is the desire of well-intentioned technologists to rush into hardware applications before the educational problem has been well defined and documented and before required courseware is available in sufficient amounts to support learning requirements. There is also the perception that technology will replace or displace people; who wants to be put out of work by a machine? With the bulk of expenditures for education being in the personnel category, replacing people with technological devices may well be one of the most alluring cost-reduction alternatives.

For many, technology is equated with things such as assembly lines and hardware, e.g., computers, television, etc. This is unfortunate because it should also be seen as a process--the application of logical reasoning and science to the identification and solution of human problems.

Definition of Educational Technology

At this point it would be useful to share definitions found in the literature and to indicate which definition will be used in this particular study. One of the most commonly cited definitions is the one offered by the Commission on Instructional Technology which defines it as:

> . . . a systematic way of designing, carrying out, and evaluating the total process of learning and teaching in terms of specific objectives, based on research in human learning and communication, and employing a combination of human and nonhuman resources to bring about more effective instruction (Tickton, 1970. p. 21).

A somewhat lengthier definition is offered by Scanlon and Weinberger:

> Educational technology is concerned with the facilitation of human learning through the systematic identification, development, organization, and utilization of a full range of learning resources and through the management of these resources. Learning resources include the people, materials, settings, tools and equipment and activities that are specifically designed for instruction and that exist are utilized for instruction (sic). It includes, but is not limited to, the development of instructional systems, the identification of existing resources, the delivery of resources to learners, and the management of these processes and the people who perform them. Thus, through the use of educational technology, alternative institutional patterns can be provided for the facilitation of learning (1973, p.7).

Yet another definition can be found in the report of the White House Conference on Children where educational technology is defined

as a process that:

> Identifies the needs of learners, individually and collectively
>
> Determines what must be done to meet those needs and considers alternative solutions and options
>
> Involves the individual learner in determining the best way to meet his needs
>
> Designs and implements the selected strategies and tools
>
> Continually evaluates their effectiveness
>
> Revises when necessary (1970, p. 150).

How do these definitions differ from one another? Do apparent differences make any real difference in how to go about designing or appraising technological solutions to educational problems? Let's begin seeking answers to these questions by examining the contents of Table 1 which appears on page 8.

First of all, it is apparent that each definition stresses the systematic design (Phase 3.0) of instruction and learning. Moreover, the artifacts of technological applications (i.e., tools such as television, computers) are salient in only two of the six phases identified: in the design phase (3.0) when alternative means for delivering instruction are considered; and in the implementation phase (4.0) where instruction and learning take place. Secondly, the three definitions differ in emphasis regarding problem definition and front-end analysis. The Commission definition states that design should focus on the attainment of specified objectives (Phase 2.0). Although this is a necessary step when beginning a design task, the assumption seems to be that the specified objectives are the "appropriate" or the most useful ones for learners and therefore are also most valuable for society. Apparently, the Scanlon and Weinberger definition takes objectives as a "given" inasmuch as no mention is

made of them. On the other hand, the White House Conference definition suggests that design of any solutions to an educational problem should begin with an assessment of learner needs (Phase 1.0). The implication is that learning objectives should not be taken as givens but that they should be carefully evaluated and judgments made regarding their usefulness for the learners involved.

TABLE 1

A Comparison of Three Definitions of Educational Technology

	Commission on Instructional Technology	Scanlon and Weinberger	White House Conference
1.0			Identify learner needs
2.0	Start with specific objectives		Determine solution requirements (objectives) to meet needs
3.0	Design systematically employing a combination of human and nonhuman resources	Design systematically utilizing a full range of learning resources: people; materials; settings; tools; equipment; activities	Design systematically considering alternative solutions, strategies, and tools
4.0	Implement instruction employing a combination of human and nonhuman resources	Implement instruction via systematically designed organization and management using a full range of learning resources	Implement instruction using systematically designed strategies and tools
5.0	Evaluate the total process of learning and teaching		Evaluate effectiveness on a continuing basis
6.0			Revise when necessary

Thirdly, the definitions differ in the emphasis that is given to evaluation (Phase 5.0) of technological applications. The Scanlon and Weinberger definition makes no reference to evaluation at all. Although the Commission definition identifies evaluation as a desired activity, it fails to specify any relationship between evaluation and revision or renewal (Phase 6.0) of the technological applications being implemented. The White House Conference report makes evaluation and revision an explicit part of its definition of educational technology.

It is noteworthy that all three definitions place an emphasis on the appropriate use of both human and nonhuman learning resources to facilitate learning. If dehumanization occurs during implementation of technological applications, it would be due to decisions made by designers or implementors and not due to anything inherent in the concept of educational technology as defined here. The principal differences among the three definitions appear to be the relative emphasis given to: problem identification; problem solving tactics; and the role of evaluation in monitoring and maintaining solution effectiveness.

The definition which we favor and will therefore rely on in this report is the one offered in the Report of the White House Conference. It is the most comprehensive of the three and has built into it self-correcting mechanisms not evident in the other two definitions. The two self-correcting mechanisms are well placed in that the first occurs at the beginning (Phase 1.0) in the form of assessing and validating learner needs. The other self-correcting mechanisms occur after implementation in the form of on-going evaluation (Phase 5.0) which is intended to determine the effectiveness

of a technological application, and revision as required (Phase 6.0) based on feedback obtained from continuous evaluation.

Why a System Rather Than a Systems Approach

Applications of technology can be powerful means for increasing the efficiency and effectiveness of education. However, just because stated goals and objectives are being achieved more efficiently and effectively says nothing about their usefulness to learners or to the society in which they will live and work. Is there a way to avoid pursuing irrelevant or useless educational objectives--a situation for which educators have often been blamed? Is there a relationship between the kinds of goals we choose and the problem solving and design processes we use to approach educational problems? The following discussion is intended to shed some light on possible answers to these fundamental questions.

Most applications of educational technology and instructional design are based on one of two prevailing approaches: the systems approach; and the system (no s) approach. Although there is a good deal of overlap in these two conceptual approaches, there are some subtle but significant differences which affect the way in which curriculum designers and educational technologists go about seeking solutions to educational problems. A comparison of these two approaches will make these differences more clear.

For example, Kaufman (1972) defines a system approach as a systematic way for identifying and defining problems as well as resolving them. The process of validating and verifying problems differentiates it from other so-called systems approach models which usually only address the resolution of problems. A system approach has six generic steps which are considered to be basic to the identi-

fication and resolution of all problems. The steps include:

1.0 Identify problem based upon needs (with needs defined only in terms of gaps in results)

2.0 Determine solution requirements and identify solution alternatives

3.0 Select solution strategies from among alternatives

4.0 Implement selected strategies and tools

5.0 Determine performance effectiveness

6.0 Revise as required (at any or all previous steps)

(The reader will note that this is basically the same model as that presented in the White House Conference on Children report.)

Cleland and King (1968) define a systems approach as a process for resolving problems within the context and confines, usually, of an organization or a presenting problem which is given as important. Systems approaches have several different forms, but most have the following characteristics in common:

1. Systems approaches look at problems and solutions as occurring in a dynamic and interacting environment which has to be accounted for in any useful solution;

2. These approaches look at alternative methods and means for best achieving goals or objectives presented with the problem;

3. They select solution strategies and alternatives based upon the most efficient and effective way to meet the objectives;

4. Solution strategies and tools are managed, implemented, and controlled on the basis of interactions and interfaces where a change in one area of a system causes changes, potentially, in all other areas;

5. Revisions are made on the basis of evaluation of the extent to which goals and objectives were met.

If we compare these two models, we find that the steps of the systems approach are most closely aligned with system approach steps 3.0, 4.0, 5.0, and 6.0. The principal difference between the two

models seems to be in the way problems are defined and identified. Although systems approach advocates would tend to agree that the validity of the problem is a crucial issue, the amount of effort and methods which are usually employed to validate a problem suggest that systems analysts are prone to accept perceived needs and specified objectives as "givens" rather than as objects for further analysis, validation, and verification. Although identifying goals and objectives is a required step in any systematic design process, there are some fundamental questions which should be answered before proceeding to use initially stated goals and objectives as the basis for solution selection or solution design. These questions include: Are the stated goals and objectives the most useful for the individual learner and his or her society? Are there other goals and objectives which would be more useful? What criteria should be used to judge the utility of a given set of goals and objectives?

According to Kaufman (1970):

> Many educational projects claim to be systematic approaches simply because their objectives are stated in precise, measurable terms . . . Objectives may be quite measurable and precise while being trivial or even wrong! Objectives must not only be measurable, but meaningful as well (p. 136).

The utility of following a system approach should now be more apparent. It utilizes the solution selection, solution design, and solution evaluation features of systems approaches; but it also goes one critical step further because it forces the educational technologist to look outside of the education "system" in order to identify and validate learner needs. In this way, the opportunity to redesign or to create a more responsive and more useful educational system becomes a reality. Conversely, if we are willing to accept statements of perceived need uncritically, (e.g., present graduates

can not read and write at an acceptable level) we may rush to premature, narrow, and ultimately ineffective solutions such as hiring more teachers in required specialties, adopting new curriculum materials, introducing computer-assisted instruction, etc. Even if such performance gaps are verified, a system approach should force us to look at solution requirements and solution alternatives more broadly rather than to proceed on the assumption that removal of these performance gaps is the sole responsibility of the English department rather than a responsibility of the entire school and community. Kaufman (1970) adds further clarification when he states:

> "Systems" Approaches tend to look at more than one system and to determine ways of combining and integrating the systems to solve problems. The System Approach tends to design, from the beginning, a single system for meeting requirements. It emphasizes starting the system design process from needs, whereas most Systems Approaches tend to assume that needs are already identified and that solutions only have to be systematically selected and combined to achieve stated objectives (p. 152). . . . What is required is a common set of process understandings so that relevant and practical tools can be identified, implemented, evaluated, and revised. Before this occurs, educators must begin to make careful distinctions between "what" and "how," between "products" and "processes," and between "means" and "ends," while also acknowledging how these features interrelate (p. 180).

What Makes Technological Applications Effective Tools for Learning

Critics of educational technology often assume that no "teacher" is present when direct instruction of learners is done by nonhuman instructional devices such as the computer, programmed texts, or instructional television. Brish disputes this notion when he states:

> A television set does not replace the teacher or the need for the teacher. Television does not produce or teach lessons. When direct instruction is presented by television a teacher is doing the teaching. What is taught and how it is taught depends on that teacher and is determined by the educational philosophy of that teacher . . . (1961, p. 50).

The point being made here is that when learning materials are being designed and produced for delivery by either a human or nonhuman "teaching" device, the same care and attention must be given to lesson design and development as would take place if the instruction were to be done in a face-to-face situation. There is a difference, however, which must be acknowledged. And that is that the mediated teacher (Heinrich, 1970) may be preparing learning materials for learners he or she may never see or know. One potential consequence of this is that such materials may not be particularly effective. They may be either too easy or too difficult for a given learner population. They may lack interest value and therefore reduce learner motivation. Effective materials design depends on valid needs assessment data and learner analysis. Once materials are designed and produced, their long term effectiveness depends on judicious use with appropriate learner populations. Using systematically designed learning materials "just because they're there" does not insure required results.

Chu and Schramm (1967) analyzed a variety of program formats for instructional television and concluded that effective use of television grows out of attention to the same basic requirements of good teaching, rather than to any fanciness that might be peculiar to television. They suggest that effective use of television depends, like all instruction, on qualities such as simplicity, good organization, motivation, practice, knowledge of results, rest pauses at appropriate points, and cues that direct the pupil to the essential things he or she is to learn. Wells (1973) concludes that these general considerations can probably be applied to the other media forms as well.

Advantages of Technological Applications

In the previous section it was argued that the effectiveness of mediated instruction delivered via nonhuman instructional devices depends on effective design and production by live teachers. One might be tempted to conclude, therefore, that there are no unique advantages to the use of technological applications. Wells (1973) counters this when he states:

> Radio and television can extend schooling to areas that receive no schooling and can provide a wide variety of auditory and visual experiences and demonstrations that might otherwise be unavailable. Programmed and computer assisted instruction allow for scheduling flexibility and individuality in progression to specified goals. Several studies have demonstrated the savings in time resulting from programmed and computer assisted instruction, even when there are no significant differences in cognitive performance on a comparison with conventional instruction (1973, p. 5).

The notion of extending schooling may seem gratuitous in American education except, perhaps, for a few Indians on remote reservations or for Eskimos in Alaska. A closer look however, suggests that there are many classrooms which, for one reason or another, lack qualified teaching personnel in certain subject matter areas such as science, drug abuse education, or whatever. The same would hold true in providing post graduate instruction to professional practitioners (e.g., in medicine, business, teaching, and public administration) who require upgrading of skills but find it difficult, if not impossible, to leave their work situations to spend a term in residence at the nearest university. For example, the Open University in Great Britain has as one of its largest target groups public school teachers desiring to obtain advanced degrees and permanent teaching credentials. Instruction is offered to these learners at a distance via television, audio tapes, films and print materials. Students under this plan

are also expected to attend seminars at designated centers for brief periods of intensive face-to-face interaction with a faculty member and student peers. In this way, the learners are not completely deprived of face-to-face contact with teaching personnel or other students.

Summary

The purpose of this section has been to define and discuss the nature of educational technology. An attempt was made to distinguish between technological applications (e.g., computer-assisted instruction, instructional television, etc.), and the technological processes involved in designing the applications. Thus, educational technology is seen as:

- A problem solving and design process

which

- Utilizes human and nonhuman resources to solve educational problems

One other salient feature of the definition of educational technology which we have chosen to use for this study has to do with validation of goals and objectives and self-renewal of an educational system. Thus, applications of technology to education should:

- Specify goals and objectives based on educator, learner, and societal needs
- Evaluate applications on a continuing basis and revise as required

The practice of educational technology is based on what is commonly known as the systems approach. One of the shortcomings of the way in which the systems approach has been applied to educational problems has been the uncritical acceptance of goals and objectives stated by curriculum planners and educators. Frequently, the resulting programs and materials are irrelevant to learners' or societal

needs. To overcome the problem of narrowness brought on by practitioners of the systems approaches, we advocate following a system (no s) approach. In this approach, the system of interest is society and education is but one subsystem within it. Inasmuch as what schools do is supposed to serve society, the logical place to begin curriculum design is by determining learner needs vis-a-vis the survival requirements of the society in which they live. Therefore, any goals or objectives specified for a school curriculum should be validated against criteria external to that school, i.e., from the social environment in which the learner will have to function upon exit. Applications of educational technology should therefore be based on:

- A system (no s) approach with the system of interest being the community and region in which a school resides
- Goals and objectives selected for a school's curriculum should be validated against societal survival requirements which have been derived from the social environment external to the school.

The effectiveness of technological applications as instructional tools depends on satisfying the same conditions as effective instruction offered by live teachers. These factors include:

- Simplicity
- Appropriate and useful organization
- Motivation
- Practice
- Rest pauses at appropriate points
- Cues that direct the learner to essential things

And finally, four advantages of technological applications in education were identified. They include:

- Extending schooling to areas where no schooling can ordinarily be provided
- Providing a wide variety of auditory and visual experiences and demonstrations that might otherwise be unavailable
- Programming which allows flexible scheduling and individuality in rate of progression
- Saving of time for students to reach prespecified levels of learning.

2. Costs and Effectiveness of Selected Technological Applications

This section of the report deals with data on the effectiveness of four varieties of technological applications in education. The instruction delivery and support systems reviewed include: instructional radio (IR); instructional television (ITV); computer-assisted (CAI) and computer-managed instruction (CMI); and programmed instruction (PI). Achievement test scores, either teacher-made or standardized, are the measure of effectiveness most frequently cited. Inasmuch as future adoption of technological innovations depends on receiving favorable reports from those who have actually tried the innovation, affective impact of the various applications will be cited whenever such data are available.

Instructional Radio

Although there is an abundance of literature dealing with IR usage in the United States, most of it was undertaken during the 1930's and 1940's. A task force appointed by National Educational Radio (1973) reports that radio broadcasting and associated audio technologies are seriously underutilized in American education today, despite wide and effective use by educators elsewhere in the world (p. 6).

Because very little systematic evaluation has been conducted on IR in the United States, we must turn to data gathered in other countries, especially the developing nations, for evidence of effectiveness. Before discussing reviews of such data, the reader should be forewarned of the peril involved in making generalizations concerning the effectiveness of IR in the United States based upon reported success in other cultural settings. Any educational system must be

viewed as a functionally differentiated subsystem of the broader social system in which it is embedded. Many of the studies to be discussed in this report took place in educational systems with objectives and priorities very different from those in the U. S. The social, political, economic, and educational factors that influence how an educational system will incorporate a technological application such as IR have generally not been discussed. Nor do the studies which have been reviewed discuss organizational or operational aspects of an educational system which could influence the effectiveness of IR. As an example, we should not assume that because IR programs have been shown to be effective within the structure of the Japanese educational system that they would also be effective in the State of Florida.

The introduction of a technological innovation such as IR in any educational system requires that changes be made in traditional or ongoing practices. Effectiveness is often dependent upon the extent to which such changes can be brought about. Most educational planners would agree that changed instructional practices are dependent not only upon the organizational and operational variables mentioned above, but also upon human factors: beliefs, attitudes, and past experiences. At this time there is very little information available on how such human factors influence the acceptance and effective use of IR. In those cases where such data do exist, the reviewer is often faced with the problem mentioned earlier concerning the validity of generalizing across cultural settings.

Finally, it should be noted that reviews of IR have rarely addressed effectiveness in terms of specific curricular areas, types

of learning outcomes, or characteristics of the target population.

Reviews of Instructional Radio Effectiveness. Jamison, Suppes, and Wells (1974) provide the most recent and perhaps most comprehensive review of IR. Studies done in Great Britain, Australia, Japan, Thailand, and Mexico were discussed. It was concluded that when supplemented with appropriate printed material, IR is as effective as traditional instruction. However, there is a problem with such a conclusion because of the ambiguous nature of the term "traditional instruction." Does the term describe some specific method of instruction? Or does it merely describe whatever was being used in the classroom before the introduction of IR? Is traditional instruction (whatever it is) comparable in Japan, Mexico, Great Britain, Australia, Thailand, and the United States? Such questions must be considered if international projects such as those reviewed by Jamison and Klees (1973) are to be used to support selection of IR as an effective alternative to traditional instruction in Florida.

Additional reviews of IR in international settings may be found in Williams (1950) and Bereday and Lauwerys (1960). McAnany (1973) has reviewed applications in both formal and non-formal school settings.

In a review of educational television Chu and Schramm (1967) drew the following conclusions which are also relevant to learning by IR:

> Given favorable conditions, pupils can learn from any instructional media that are now available (p. 151).
>
> The use of visual images will improve learning of manual tasks as well as other learning where visual images can facilitate the association process. Otherwise, visual images may cause distraction and interfere with learning (p. 162).
>
> Student response is effectively controlled by programmed methods, regardless of the instructional medium (p. 172).

Similar conclusions concerning the effectiveness of IR were reached by Forsythe (1970). The characteristics and uses of radio identified in his review of forty-one articles include:

1. The ability to present student with events as they happen. Radio can be combined with visual elements to create an emotional impact which may heighten the effectiveness of instruction.

2. Radio provides listeners with a source of involvement and allows the listener to hear authorities or programs that are beyond the scope of the typical school system.

3. Radio may be used jointly with other media such as television. Multiplexing offers the opportunity to use single-image facsimile transmission or the use of electrowriters.

4. Radio is capable of copying almost all educational projection properties of television at considerable lower production and reception costs.

5. Radio could also be used to effectively deliver such services as in-service teacher training, continuing professional education, community service, health, and vocational training.

6. Visual elements in learning are not always helpful and multi-channel communication may not be inherently more effective than single channel presentation.

Comparisons of Instructional Radio with Other Media. McLuhan (1964) presented the results of a study which compared IR and television. Four randomized groups of university students were given the same information at the same time about the structure of preliterate languages. One group received it via radio, one from television, one from lecture, and one group read it. For all but the reader group the information was presented in a straight verbal flow by the same speaker with no discussion or questions allowed. Each group received one half hour of exposure to the material and took the same quiz at the end of that time. Students who had been exposed to the television and radio presentations performed better on the quiz than students exposed to the lecture or individual readings. The group

exposed to television scored much better than any of the other groups. The experiment was repeated with another group of randomly assigned students and each medium was used in a manner assumed to tap its full potential. The materials for radio and television presentations were dramatized and many auditory and visual features were added. The lecturer made use of the blackboard, questions, and class discussion. The printed presentation was revised so that illustrations and page layout stressed the points covered in the quiz. Radio and television exposure again resulted in higher quiz performance than lecturer or print. Surprisingly, however, radio exposure resulted in better performance than television. It was concluded that when television was heavily dramatized it became over-defined, leaving little opportunity for student participation.

William, Paul, and Ogilvie (1957) conducted a study on retention in relation to four different media. The same abstract lecture was presented simultaneously to a television studio audience, on television, on radio, and in print to four groups of college students matched on grade point average. Each group took a thirty-minute multiple choice examination immediately after the lecture and again eight months later. Television, radio, and reading ranked in that order of effectiveness and the order was unchanged eight months later. Those in the television studio did no better than the reading group.

Rothney and Hausen (1947) reported a University of Wisconsin study to determine the effects of a radio program designed to teach children to recognize the basic value of the individual, to judge people in terms of their own merits, and to overlook differences in race, religion, and national origin. The results showed that 97% of

the students liked the broadcast, and that 75% of the teachers believed the program produced improved pupil attitudes. There were significant differences between listening and nonlistening groups of students in terms of favorable attitudes towards members of groups other than those of which they were a part.

Bannister (1970) compared the effectiveness of two American history courses for college students taught by two media methods. One group of students received instruction on taped lectures accompanied by filmstrips, student response sheets, and seminars. The experimental group received thirty-minute FM broadcasts three evenings a week, which were supplemented by illustrated printed material. Both groups had textbooks and other reading assignments. Results showed that radio broadcasts accompanied by printed material were as effective as an on-campus multimedia program using tapes, film-strips, and student response sheets.

Taylor (1972) conducted a radio program designed to assist elementary teachers in improving the communication skills of their students. The radio programs were largely composed of nonverbal sounds often found in a middle-class home but normally absent from the home of the culturally-deprived child. The sounds usually told some sort of story and the students were encouraged to listen, imagine, and project opinions about what the sounds could signify. Results showed that the programs generated a great deal of interest on the part of students and by the end of the first year teachers reported some improvement in communication skills.

The research cited above and the numerous studies reviewed support the conclusion that IR compares favorably in terms of

effectiveness with other presentation methods such as lecture and television. It should be noted, however, that many of the studies are old, statistical controls were often lacking, length of instruction was generally brief, considerable instructional support was provided by teachers and printed materials, and identification and evaluation of specific types of learning outcomes was seldom attempted.

Maximizing Instructional Radio Effectiveness. A set of critical factors associated with the planning, development, and implementation of a successful instructional radio project could not be identified on the basis of the literature reviewed for this paper. The state of the art at this time is such that it is impossible to say with any certainty what makes some radio projects mildly effective and others outstanding.

A notable exception is the recent attempt by Manduley (1976a, 1976b) to identify factors which influence teacher usage of IR. Data were collected from over 200 teachers and their administrators in 80 selected public elementary schools in Washington, D.C. during the 1973-74 academic year. Manduley did not view IR as a potential replacement for the classroom teacher, but rather as a tool for making the presentation of information more productive. It was concluded that the attitude and the methods and techniques the teacher employs, or fails to employ, can mean the difference between a successful or poor broadcast lesson.

Manduley proposed that teacher activities which influence effectiveness of a radio program be divided into three phases: preparatory, participatory, and follow-up. The most valuable preparatory activities were identified as developing student

readiness for a radio broadcast by providing preliminary explanations or discussions regarding the reason for program usage, listing key words used in the lesson, and planning activities to supplement the listening experience. Participatory activities of value discussed included an active interest in the program shown by the teacher. The amount of interest and participation in a radio program shown by the teacher seemed to be mirrored by students in the class. Post-broadcast or follow-up activities seemed to be most effective when they sought to fill in gaps in the presentation, clarify misunderstandings or extend learning to new but related areas. A lecture which attempted to reteach the broadcast material did not seem to increase learning effectiveness.

Attitudes and behavior of the school administrator were also directly related to teacher attitudes toward IR. The more assistance administrators provided teachers in terms of materials and supplies for radio programs the more favorable were the attitudes expressed by teachers concerning the instructional value of the programs. Some teachers were found to require assurance that the radio was not going to replace them in the classroom. Clarification of their role in relation to IR resulted in more favorable attitudes and greater use. To many teachers it seemed important to emphasize that although the radio could present information and stimulate children to learn, it could not hear their questions, see their faces, or understand their individual needs and respond on that basis. Some teachers required assurance that such activities were still within their role expectations.

Teacher training was also found to be an important factor in utilization of IR. The more training teachers received in radio usage, the more positive were their attitudes, and the more they initiated preparatory, participatory, and follow-up activities in connection with broadcasts.

Costs Associated with Adoption of Instructional Radio. Consideration of costs in any technological application to education begins to make sense when we realize that adoption usually entails acceptance of a commitment to pay now and reap the benefits later. An excellent review of the cost factors with which the educational planner should be familiar when considering adoption of IR is provided by Schramm, Coombs, Kahnert, and Lyles (1967). The review identifies initial costs, relationships between costs and amount of use, unit costs, production costs, and examples of methods for estimating expenditures. Estimates for initial investment range from $100,000 if existing facilities are limited, to $25,000 to $50,000 if existing facilities can be extensively used. Comparable figures for educational television range from $38,000 to $8,000,000.

In terms of average unit costs, Schramm et al. (1967) reported that costs for school broadcasts in which radio provided a substantial part of the educational program could be as low as $.01 to $.02 per student-hour. This compares favorably to the $.05 to $.15 per student-hour when television is used. Radio forums in Tonga, which number 152, are estimated to cost $.32 per student-hour. If the number of forums could be raised to 1,000 it is estimated that the average cost would drop to $.06 per student-hour. India, with 2,000 forums, spends $.09 per student-hour. In Japan, where the average

annual cost per secondary school pupil is about $349, the cost of correspondence-plus-radio was estimated to be $91 per student per year. Correspondence-plus-television was estimated to be $148 per student per year.

Bourrett (1971) has presented arguments in favor of radio over television instruction as a low cost alternative for reaching rural areas. He cites evidence which shows that installation and programming costs for television are three to five times that of IR.

Jamison, Klees, and Wells (1976) have suggested a methodology for estimating the costs of IR in developing countries; this methodology should be examined for application in the United States also. Cost information on IR may be obtained in two ways. An educational planner may use data from ongoing or planned projects to determine what cost experience others have had. He or she may also formulate cost functions from component costs obtained from sources such as supply and equipment catalogs.

Jamison and Klees (1973) emphasize that in many previous estimations of costs associated with IR, a clear distinction has not been made between fixed, variable, capital, and recurring costs. The model they propose for estimating the cost of providing IR is linear and takes the form $TC(N) = F + VN$, where TC equals total costs, F equals fixed costs, and VN equals variable costs. This model is based on the assumption that average cost declines as N increases (by spreading fixed costs over more units) and when N becomes very large the average cost is close to the marginal cost. The model is further based on the assumption that program preparation and transmission are fixed costs which are independent of the number of students using the system.

Reception costs, however, tend to vary directly with the number of students (N).

Fixed and capital costs have often been confused in the past. Some fixed costs are recurrent such as the electrical power required to operate a radio transmitter. Some capital costs are variable, such as the receiver component of reception costs. It is important that the educational planner interested in IR remember that fixed and capital costs are distinct but that in most cases the major capital expenditures are associated with substantial fixed costs.

An anlysis of cost data led Jamison and Klees (1973) to make two conclusions concerning IR. First, the costs of IR can be expected to range from $.003 to $.03 or $.04 per student hour which is about 1/5 as much as intructional television. For any given fixed cost, the high end of the unit cost scale might be reached with several thousand students and the low end with several hundred thousand. Second, the high front-end costs and rear-end utilization of technology of any kind require that projects last 10-20 years to allow average unit costs to fall to a reasonable level. In their opinion, if there is a substantial probability that a project will not last 15 years, its initiation should be reconsidered (p. 44).

Jamison et al. (1976) remind educational planners that opportunity costs should also be taken into consideration when evaluating IR. Opportunity cost may be defined as the value to the decision maker of what has been turned down in order to be able to choose a given alternative. In most school systems where the expenditure per student is a fixed amount, having more of one thing (or something new like IR) implies that there is going to be less of something else. Since the

largest expenditure in most school systems is for teacher salaries, many educational planners would like to be able to look at the opportunity cost of IR in terms of teacher costs. (For a procedure to calculate opportunity costs, see Jamison et al., 1976, pp. 27-28.)

There is agreement that in those cases where IR costs have been evaluated in other countries they are considerably less than traditional classroom instruction. As Theroux (1975) has pointed out, however, if radio is used only to supplement regular teachers, as has often been the case in the United States, the cost may be more than traditional instruction.

Although models exist for estimating the costs of providing IR, they have rarely taken into account the costs of providing printed materials to accompany radio broadcasts or of training teachers to fit broadcasts into a total instructional program. Given the evidence presented by Manduley (1976b) on the importance of supporting materials and teacher preparation, cost models should be revised to include such factors. Perhaps there is some validity to the claim that what is done and how it is done within a medium is more important than which medium is used. If so, we must be careful to include cost estimates for all the critical "whats" and "hows" that will make adoption of a technological application like IR an effective alternative with which to present instruction.

Cost Comparisons between Instructional Radio and Instructional Television. Drawing on experiences from field projects and planning studies, Jamison et al. (1976) estimated costs to implement and operate an instructional program using either IR or ITV based on the following assumptions. The number of students to be served by both

delivery systems would be 200,000; the total number of hours of instructional programming would be 500 and would comprise 10% of all instruction provided to learners. The 200,000 learners would all live within a 100 mile radius of the transmission site. There would be 70 students per receiver; the total number of reception sites is 1,430. Capital and annual recurring cost figures have been estimated and are listed in Table 2.

The life of these projects is assumed to be 20 years. Recurring costs for central administration, annual production, annual transmission and receiver maintenance for the life of the project are estimated to be: $8,971,440 for IR; $16,054,000 for ITV. (These estimates do not include costs that would be required for electric power for electronic equipment or for print materials required by students.) A comparison of capital outlay requirements is even more striking. Over the 20 year life of the project, capital costs are estimated to be: $1,707,100 for IR; and $13,172,256 for ITV. (These estimates of capital costs do not include interest charges required to obtain funds either to build production facilities or to purchase production, transmission, and reception equipment. Interest costs would be considerable in view of the large initial capital outlay required for production and transmission equipment and the facilities to house them.) With the exceptions noted above, the total estimated project costs are: $10,678,540 for IR; and $29,226,256 for ITV.

Assuming that these applications have provided 10% of the instruction for 200,000 learners per year, we can calculate the average unit cost over the 20 year life cycle and find that it is $.021/SCH

TABLE 2

A Comparison of Costs for IR and ITV

Cost Component	Assumed Cost for Radio	Assumed Cost for Television
Start up costs	$ 300,000	$ 300,000
Annual central administration cost	60,000	80,000
Production facility capital cost	230,000	2,316,000
Production equipment capital cost	160,000	1,571,428
Annual production cost[a]	320,000	540,000
Transmission equipment capital cost	480,000	1,570,000
Transmission facility capital cost	25,500	26,000
Annual transmission cost	68,000	177,000
Receiver capital cost per receiver	20	200[b]
Receiver-related equipment capital cost	--	320
Reception facility capital cost	40	1,100
Hourly cost of power	.025	.186
Hourly receiver maintenance cost	4	40
Print cost per page	.005	.005

[a]Programming is assumed to be provided for 10% of the total instructional time of 1,260 hours (35 hours per week for 36 weeks) for students in four different grades.

[b]Black and white TV receiver. (Note: Data obtained from Jamison et al., 1976, pp. 127-130.)

for IR (based on a total expenditure of over $10 million) and $.058/SCH for ITV (based on a total expenditure of over $29 million).

Assuming that these cost estimates are valid, ITV is over two times as expensive as IR. However, there is no evidence which suggests that ITV is also two times more effective in promoting comparable learning outcomes. With print materials to provide graphic support, IR will probably produce as much learning as ITV for the kinds of outcomes that have been taught by previous applications of these two media.

Instructional Television

ITV has a history of use in both the developed as well as the developing nations of the world. However, the rationale for using ITV has differed in these two world settings. In the United States, for example, ITV was initially proposed and tested as a means for improving the quality of education and the effectiveness of student learning. More recently, the emphasis has shifted toward reducing instructional costs or to providing instruction for learners at a distance, e.g., professional engineers whose job requirements do not permit them to come on-campus for classes (Jamison et al., 1976). On the other hand, some developing nations have looked to ITV as a way of overcoming the lack of qualified teachers. To train the required number of teachers would be a long and costly effort. Countries such as El Salavador and Mexico have therefore sought to compensate for the lack of qualified secondary school teachers by initiating educational reforms based on adoption of ITV. The Republic of South Korea faced a similar problem; their objective was to permit

a larger number of children to go on to middle school without appreciably increasing expenditures for education. ITV played a key role in this educational reform also (Morgan and Chadwick, 1971).

Instructional Television and Achievement. Determining the effectiveness of ITV is a well researched area. For example, Chu and Schramm (1967) have reviewed over 200 studies that contain a total of 421 comparisons of ITV with traditional instruction. Dubin and Hedley (1969) have surveyed the effectiveness of ITV at the college level. On the basis of their review, they were able to make 191 comparisons between ITV and traditional instruction. A significant addition to this large body of research literature was made by Jamison, Klees, and Wells (1976) who reviewed the costs and effectiveness of large scale applications of ITV both here and abroad. The Electric Company, a television series designed to assist poor readers in the early elementary grades has also been the object of research investigators including Ball and Bogatz (1973) and Herriott and Liebert (1972). The Electric Company is of special interest because of its focus on the teaching of a selected set of reading skills.

Of the 421 comparisons reviewed by Chu and Schramm, 64 were at the elementary level, 122 at the secondary level, 202 were at the college level, and 33 were with adults. It seems clear that ITV has been applied to learners of all ages. But more significantly, Chu and Schramm concluded that students at all grade levels learn well from ITV although younger students seem to learn more from it than do older students. Chu and Schramm also looked at subject matter fields in which ITV applications were attempted. They found that ITV has

been used to teach mathematics, science, social studies, humanities, languages, and other kinds of skills. Moreover, data reviewed indicates that the effectiveness of ITV cuts across almost every subject field.

In their review of applications at the college level, Dubin and Hedley (1969) found that ITV was slightly more effective in 102 out of 191 comparisons and traditional instruction was favored in 89 of them although most of the observed differences were not statistically significant.

One of the most systematically designed and developed applications of ITV is the program series The Electric Company. This program is the product of the nonprofit Children's Television Workshop (CTW). CTW has been heavily subsidized by the federal government and private foundations including: the U. S. Office of Education; Corporation for Public Broadcasting; Ford Foundation; and the Carnegie Corporation of New York.

The Electric Company was designed on the basis of input from educational advisors, psychologists, and a research and development team employed by CTW. The program formats and instructional strategies were carefully tested and revised by the research and development team before large scale production was begun.

In its first season, The Electric Company's target audiences were second graders who scored in the lower half of their grade on standard reading achievement tests, and third and fourth grade students who scored in the bottom 25 per cent of their grade norms. The program was designed to achieve a specific set of curriculum goals that

were developed by a panel of educational advisors and CTW's research staff. The performance objectives for learners were directed toward decoding skills, i.e., the process of extracting meaning from written messages.

Impact of The Electric Company was evaluated by two different research teams, one at Educational Testing Service (ETS), the other at Florida State University.

According to Ball and Bogatz (1973):

> The ETS study clearly indicates that as a result of watching The Electric Company in school during the 1971-72 inaugural broadcast year, viewing classes made significantly greater gains than non-viewing classes in the reading skills the program was designed to teach. The program had a clear and significant impact on its primary target audience--second grade children who were in the bottom half of their class as indicated by standardized reading test scores--indicating the program was an effective instructional supplement for children who were beginning to experience reading difficulty (p. 2).

Herriott and Liebert (1972) studied the breadth of utilization of The Electric Company and reported the following results:

> Within two months of its appearance in October, 1971, The Electric Company was being used by 23 percent of the elementary schools in the United States.
>
> In schools having full television viewing capabilities the number using The Electric Company jumped to 45 percent.
>
> In large cities, The Electric Company was being used by 70 percent of all schools having full television capabilities.
>
> Approximately two million pupils were viewing The Electric Company at school. This figure includes one out of every four second and third graders in large cities (p. 4).

And of particular interest to the State of Florida is this finding:

> The least informed group, and the least use of the series, both occurred in the Southeastern states where CTW reports that broadcast scheduling was probably one factor in low utilization of the program. While all public stations in the area carried the programs, a substantial percentage of them did not do so during school hours (p. 4).

The Hagerstown ITV System in Washington County, Maryland, is perhaps the oldest and has the longest continuous history of any ITV application in the world. Initial transmission began in 1956 and has continued ever since. The ITV system was reaching 18,000 students (or nearly 100 percent coverage of grades 1-12) by 1959. Citing results provided by the Washington County Board of Education, Jamison et al. (1976) report gains by TV taught students greater than those achieved by nonTV students or students with less exposure to televised instruction. Of particular interest were results reported for students in rural schools in the 5th grade. Mathematics achievement for 5th graders in May 1958 (before ITV) was 5.34 grade equivalents. In May 1959 (after one year of ITV), 5th graders were averaging 5.71 grade equivalents. In May 1960 (after two years of ITV) 5th graders were achieving at 6.03 grade equivalents, and by May 1961 (after three years of ITV), 5th graders were up to 6.11 grade equivalents. Unfortunately, no information on statistical significance is reported.

With the research results taken as a whole, it seems clear that students can learn as well, if not better, when taught by mediated teachers via ITV.

Attitudes Toward Instructional Television. It seems clear that ITV has had the benefit of wide utilization over a wide variety of subjects and age levels. How well do users like it? Chu and Schramm (1967) concluded that:

> . . . the research evidence makes attitudes toward instructional television seem rather more favorable than one would expect from the experience reports that circulate. Regardless of this evidence there is good reason to think that some resistance among teachers has been aroused wherever and whenever television has been introduced for purposes of direct teaching (p. 111).

At a more specific level, Chu and Schramm concluded that teachers and pupils are more favorable toward the use of ITV in elementary school than in secondary school and college. They also felt that administrators are more likely to be favorable toward ITV than are teachers. Their conclusions at the college level were that students tend to prefer small discussion classes to television classes, and television classes to large lecture classes.

Dubin and Hedley (1969) also analyzed receptivity toward ITV in their review of television applications at the college level. They found that professors are generally favorable toward ITV although a majority of them indicated that they would rather send their own children to a university using traditional instruction than to one utilizing ITV for its large introductory classes. Dubin and Hedley also examined student attitudes and found that they are likely to be more favorable toward ITV after they have experienced it than before. Although there was a substantial variation across institutions, less than one-third of the students said that they would choose ITV over traditional instruction. In terms of choosing between a large lecture course and ITV, over half of the students preferred ITV. Dubin and Hedley's overall conclusion was that:

> . . . the college student as consumer of teaching does not exhibit any significant resistance to the introduction of educational television into his own instructional program. He will take whatever method or medium of instruction is offered, damn or praise it on its merits, and get on with the business of pursuing his college education (p. 86).

In their evaluation of The Electric Company, Ball and Bogatz (1973) reported that teachers in general and first-grade teachers in particular reported favorable attitudes toward the program. Moreover, at the first grade level, parents of viewing children regarded their

children as better readers than did parents of nonviewing children. However, similar reactions were not found at higher grade levels.

The Hagerstown ITV system has also been studied in terms of impact on attitudes toward televised instruction. Wade (1967) reported that there was a general decline in teachers' receptivity of ITV as a function of school level. More specifically, 76.9 percent of the primary teachers and only 40.9 percent of senior high teachers felt that ITV provided help in instruction. In recent years, there has been an increase in the amount of criticism being directed at the project. Based on attitude surveys taken by a special committee appointed to study the problem, Jamison et al. (1976) reported that recent attitudes have been negative. Of the students surveyed, 77.5 percent felt that they learned more from a classroom teacher while 62.8 percent felt that television did not motivate them to learn. Slightly over 67 percent of the students felt that they would rather learn without ITV. A small sample of responses was obtained from the general public in Washington County. Approximately 60 percent of those surveyed felt that ITV did not contribute to learning, did not motivate students, and did not belong in the schools. Although teachers viewed ITV more positively than the general public, the teachers' opinions declined relative to the earlier survey. One other noteworthy result was that 50 percent of secondary and 75 percent of elementary teachers felt that their students were losing by the use of ITV. No explanations were offered as to why these shifts in attitude had taken place.

Costs of Instructional Television. Cost analyses provided by Jamison et al. (1976) suggest that ITV systems require relatively

large expenditures to start with. Because of these large expenditures, applications of ITV must be used for long periods of time--from 15 to 20 years--with large numbers of students in order to bring average cost per student to a level comparable or less than traditional instruction. Cost categories include:

- Central project costs for planning and start up
- Programming costs which include both capital investment in production equipment and annual production costs
- Transmission costs which include transmitters and relay systems required to send the signal to places where instruction is given
- Reception costs which include reception equipment, maintenance, power, and operating expenses, and materials required by learners.

The cost analyses presented by Jamison et al. could be viewed in several ways. In view of the purpose of this report, cost data which will be shared will address ITV applications at two levels: ITV system costs representative of a school district application; ITV costs representative of a statewide application. The figures which will be presented should be considered "ballpark" figures and, without detailed planning specifications, will probably underestimate actual costs.

Due to its long history of operation, the Hagerstown ITV project provides us with some figures that appear to be representative of school-district-size applications. Cost figures for the Hagerstown system are reported by Jamison et al. (1976) as follows:

> The initial investment in equipment for the studios and classrooms and construction of the central facility was $1,049,700. In other years of the project, new capital expenses rarely exceeded 10% of total expenses and have usually been approximately 3%. Annual expenses have increased from $724,300 in 1958 to

> $1,102,500 in 1972. Salaries for TV teachers have been 30-35% of total expenses; engineering, production and support salaries have been 20-25% of total expenses; administration salaries have been 7-8% of total expenses; and cable rental has been 15-20% of total expenses (p. 223).

The Hagerstown approach to production and programming has been to take classroom teachers and use them as studio teachers. The reader should keep in mind that programming costs are variable, however, and could range from as high as $60,000 per hour for Sesame Street, a middle range of $9,600 per hour for the Open University in Great Britain, to a low of about $100 per hour by renting a videotape from a rental library. In general, keeping local control of program production costs more than renting materials already developed by others. Reducing program costs may therefore require giving up some local autonomy in curriculum decision making as will become apparent when a statewide network is considered.

Cost figures for the Korean Elementary/Middle School Project are instructive regarding a state-wide application. In this project, approximately one-third of the direct classroom instruction is done by ITV. The lesson materials are developed and produced by the Korean Educational Development Institute. Expenditures which include personnel costs are probably underestimated because Korean salaries are low when compared to salaries in the United States.

The following data were obtained from Jamison et al. (1976).

System development and start up costs: $3,111,200. (This figure includes curriculum preparation and book writing.)

Capital costs for studio facilities: Land and buildings $1,572,000; TV studio equipment $1,200,000.

Recurrent costs of program production: $1,317 per instructional hour. (If we assume two hours of ITV instruction per day for 180 days this would amount to $474,120 per year.)

Transmission system costs: These are more difficult to estimate because of the radical differences in topography and shape of the land mass when Korea and Florida are compared. In Korea the decision was made to use aerostat sites that could transmit signals to ground relay stations which would retransmit TV signals to schools beyond the reach of the aerostat. (An aerostat is a helium filled balloon tethered on a steel cable at an altitude of 10,000 feet. Transmitting equipment is on board for relaying TV programs over a wide area.) The capital cost for the aerostats and ground relay stations is $3,044,800. (Alternatives such as a communications satellite will be discussed below.)

Recurrent costs of the transmission system: $168,000 per year.

Reception costs: They include $435 per color receiver as a fixed capital cost. (The total for Florida could be determined by multiplying $435 by the number of receivers required; a recurring cost of $82 per year per receiver would be required for power, maintenance, and spares.)

Reception site costs for print materials: Approximately $2.60 per teacher per year and approximately $2.00 per student per year. (These recurring costs could be calculated by multiplying the respective dollar figures by the number of teachers and the number of students involved.)

Transmission system costs are a significant item especially for a large scale system. Ground transmission systems can be based on (1) microwave relay towers, (2) cable systems, or (3) a combination of both. Cable systems are expensive to install and maintain. They can also be leased. For example, the Hagerstown ITV system utilizes a dedicated six-channel cable to transmit to 45 schools in a 268-square mile area. The cable is leased at an annual cost of $164,000 per year. The reader should bear in mind that the Hagerstown example is appropriate for a school-district-size application. Economy of scale could not doubt be achieved if a statewide ITV distribution network were created.

Local Community Antenna Television (CATV) or cable TV has been expanding rapidly. Some studies project that CATV will reach into two-thirds of the homes with television sets by the middle of the 1980's. How CATV systems might be linked with schools and what the

distribution charges would be is in need of further study. For example, Morgan et al. (1973) state:

> The extent to which education will capitalize on cable communications systems, which are developing primarily commercially, is uncertain. The FCC has ruled that cable operators must make available for educational purposes at least one channel in the major markets. Two other channels must be designated for public access and government uses. This is only for a period until 1977 when it is conceivable that . . . they must be used or lost. Our general impression is that there is a great deal of interest in the public access channel on the part of various groups. However, the depth of interest on the part of school systems may be less strong (p. 300).

It would be unfortunate if this cable transmission capability were lost because of a lack of timely interest on the part of public schools in Florida.

As mentioned previously, one other way of providing ground transmission of television (and computer) signals is via microwave relay towers. Jamison et al. (1976) report figures calculated by others on a per mile basis. These estimates range from as low as $1,733 per mile for a one channel system to as high as $2,950 per mile for four-channel systems.

Another alternative for mass distribution of ITV signals to schools around the state would be through the use of telecommunications satellites positioned in geostationary orbit above the earth. Some present satellites are highly versatile and can simultaneously support applications for telephone, radio, television, and the computer.

A "light" satellite (light referring to transmission capability) is estimated to cost approximately $30 million and has an expected life of 5-10 years. A "light" satellite requires signal amplification by stations on the ground. Hupe (1974) estimates that equipment for a ground receiving station could be purchased and installed for

$5,000; annual costs for operating the station are estimated to be $15,000 per year. Hupe also quotes a figure of $600 per hour for transmission via satellites on a lease basis.

A "heavy" satellite costs from $50-60 million and also has an estimated life of 5-10 years. It contains amplification equipment on board so that its signals can be received at ground level with an antenna in the $250-$1,000 range.

Even if only one channel on a satellite were leased, transmission could be continuous to local ground stations which in turn would videotape instructional programs to accommodate local schedules and provide flexibility in replaying and scheduling.

According to Hupe (1974), satellite experiments to test applications in providing delivery of health and educational services were begun in June 1974. The areas being served include Alaska, Appalachia, and the Rocky Mountain states. Although the cost of a satellite system might be prohibitive for a single state such as Florida, the capacity of a satellite is such that it could probably serve several other subscribers both commercial and educational. Another possibility would be for several states in a region to form a consortium in order to share capital, operating, and programming costs. According to Morgan et al. (1973), the economies of scale with satellites are such to require regional and inter-regional cooperation.

Hupe (1974) foresees a virtual revolution in providing access to <u>all</u> learners through the application of educational satellite systems. While depicting a scenario for the future, he states:

> From the learner's viewpoint, one can envision an attractive choice of a wide variety of learning materials from a wide variety of participating educational institutions, no matter his geographical location. Cost to learner could be less than in present systems, and reduction in external diseconomies in transportation, relocation, disruption of life or work patterns should be substantial. . . . The marketing abilities of participating educational institutions would be vastly broadened, enabling them to share their best teachers and other educational resources with a much larger learner audience, and bringing them much needed additional revenues (p. 52).

It seems clear that the capacity of a satellite to transmit a variety of signals over a vast geographic region provides a direct means for providing high quality instruction to learners of all ages within the confines of their own community if not actually within their own homes. However, a key problem to be solved would be the design and production of high quality learning materials in all required or desired subject matter fields. This, too, would be costly at the outset.

Computer Based Education

The use of computers in education has a fairly recent history. Nonetheless, usage has increased dramatically within the last few years. These applications have been diverse in form and intent. It is perhaps for this reason that so many labels have been applied to uses of the computer in education. Watson (1972) noted that at least 21 terms can be found describing educational computer systems. The situation is further complicated because terms are not employed consistently from author to author.

This ambiguity in terminology becomes a problem when one attempts to compare applications or to discuss the area in general. There are two basic strategies for dealing with this problem. First, one

can refer to uses of the computer in education without distinguishing terms (Milner and Wildberger, 1974; Seidel, Hunter, Kastner, & Rubin, 1974). Second, one can formulate a classification system for various instructional uses of the computer (Towle & Brightbill, 1976; Watson, 1972).

The three type classification which Towle and Brightbill (1976) advocate includes two of the most frequently encountered terms: computer-assisted instruction (CAI) and computer-managed instruction (CMI). CAI refers to systems in which the computer provides direct instruction. Towle and Brightbill identify five forms of CAI: drill and practice; tutorial; simulation; instructional games; and modeling. The first two are frequently cited in conjunction with CAI (Bunderson, 1972; Seltzer, 1971; Watson, 1972). Problem solving is another category of CAI which is common (Howard & Wood, 1971; Seltzer, 1971).

CMI refers to systems in which the computer manages instruction and/or aids in individualization of instruction. The number and sophistication of functions performed varies with the complexity of the system. Some of these functions include scheduling of students, scheduling of resources, record keeping, diagnostic testing, periodic testing, test scoring, grade compilation, prescription, student feedback, and test item analysis (Hansen, Ross, Bowman, & Thurmond, 1975; Middleton, Papetti, & Micheli, 1974; Towle and Brightbill, 1976).

CAI Applications. Applications of CAI can be found at all levels of education. Studies have been reported for elementary (Anastasio, 1972; Jamison, Suppes, & Wells, 1974), middle grades (Allen, 1973;

Dick, 1969), secondary (Kopstein & Seidel, 1968; Singh & Morgan, 1971), junior college (Bunderson, 1970; Mitre Corporation, 1974), postsecondary (Hooper, 1974; OKey & Majer, 1975), military (Butman & Frick, 1972), continuing education (Hall, 1976), the deaf (Ball & Jamison, 1972), and educable mentally retarded (Brown & Luyben, 1972).

CAI systems have been used in a variety of subject matter fields. For example, the Fourth Conference on Computers in the Undergraduate Curricula (1973) included CAI presentation in these areas: engineering, social sciences, natural sciences, humanities, and business. Applications have addressed learning of information and intellectual skills.

Effectiveness of CAI. It is apparent that the applications of CAI are quite diversified in both level and kinds of educational outcomes. However, it is important to ascertain the effectiveness of CAI.

The data on effectiveness are encouraging. For example, Allen (1973) reported that the effectiveness of CAI is not doubted. Watson (1972) pointed out that even critics of CAI agree that it is at least as effective as traditional instruction. Of the studies reviewed which included data on effectiveness, some found increased achievement in comparing CAI with traditional instruction, many found no significant difference between CAI and traditional instruction, but none found decreased achievement when comparing CAI with traditional instruction.

When Dick (1969) compared CAI with programmed instruction (PI), he found that low ability students had longer retention with PI.

The suggested explanation for this finding was that the hard copy of PI allowed students to review the material.

Reduction in Time. In addition to data on achievement, CAI studies have compared the time required for learning. The results show that CAI tends to reduce instructional time (Allen, 1973; Civil Service Commission, 1971; Dick, 1969; Morgan, 1969). Watson (1972) concluded that critics of CAI would agree that CAI results in less time. For example, Judd (1971) found that a combination of 4 class hours and 4-8 terminal hours could effectively be substituted for 18 class hours and undetermined hours of homework. Butman and Frick (1972) indicated that CAI enabled a 37% savings in time.

Gerrell (1972) found that group CAI (7-8 members) was as effective as individual CAI and as a control group. OKey and Majer (1975) conducted an investigation on single, paired, and multiple (3-4) users of CAI. They found no significant differences in achievement. However, there were significant differences in study time with multiple users spending the least and paired users spending the most time.

Attitude Toward CAI. Six studies indicate that attitudes have been measured as part of the investigation. However, two of these did not report the results of the attitude measures; the other four reported that attitudes of students toward CAI were favorable.

Attitudes of school systems in general may not be as favorable. For example, the Mitre Corporation (1974) does not feel that school systems will accept CAI. In a review of the literature regarding adoption of computer-based innovations, Seidel et al. (1974) cited

reports of major obstacles for development, adoption, and dissemination. Costs were listed in each category.

Costs of CAI. Just as effectiveness is an important criterion for decision-making, costs are also important. However, a discussion of costs for computer applications is complex due to the variety of factors which are considered. Some of the complexity is due to values and priorities of the author(s). Inconsistent use of terms is also a factor. For example, software may refer only to computer programming or it may refer to both computer and course programming.

An important unit of measurement reported for CAI costs is unit cost or cost/student contact hour (SCH). This unit is useful for comparing CAI systems with other media and CAI systems. However, the computation of cost/SCH may or may not be based on a common formula. For example, the following items may or may not be included: research and development (computer programming, specific courseware, etc.), capital investment (computer, terminals, software), operating costs (hardware, communication, personnel, etc.). This discrepancy becomes critical in light of the fact that the cost data which are reported do not necessarily indicate how cost/SCH was computed.

Calculation of the cost/SCH (which is an average cost) is based on an estimated number of hours usage within a given period of time. This information may also be missing. An example of the magnitude of this discrepancy can be found in the review by Seltzer (1971). He found that round the clock operation of a system resulted in an average cost of $.22/SCH whereas a calculation based on 10 hours/day for 24 days/month yielded an average cost of $2.61/SCH. Kopstein

and Seidel (1968) also reported significant average cost variation based on different levels of usage per month.

The size of the computer is another key issue in the literature. Size affects the number of terminals which can be supported and used and the potential of cost sharing with other users. Advantages of a small computer included reduced capital investment and reduction in professional staff requirements (Kimble & Heydinger, 1970). A large computer has lower operating costs (Kopstein & Seidel, 1968) and capacity for multiple use (Academy for Educational Development, 1971). However, large computer systems are more apt to be vulnerable to communication costs (Dick, 1969).

Communication costs (telephone lines or microwave relays to link terminals with the computer) are unique in that they are the only area in which the trend has not been a reduction in cost (Singh & Morgan, 1971). Thus, there has been interest in a satellite system to handle communications for large, dispersed computer systems (Ball & Jamison, 1972).

General Cost Outlook. CAI has not been considered to be competitive with the cost of traditional instruction (Allen, 1973; Morgan, 1969; Watson, 1972). Seltzer (1971) stated that the only potential for cost effectiveness is in higher education. Potential for cost reduction in high cost areas (e.g., special students, professional development programs) was also expressed by Butman (1973). Hooper (1974), however, asserted that CAI can never be cost-effective since staff is always increased regardless of claims to the contrary.

A scathing analysis was made by the Mitre Corporation (1974).

They labeled CAI as a commercial failure and set a goal to develop a new generation of cost-effective systems. They concluded that the systems should be targeted for community colleges. This was based on their analysis that neither lower cost, higher performance, nor use of an improved theory of learning would get CAI into the public schools.

Potential for Cost Reduction. Nonetheless, optimism has been expressed by many for CAI to be cost-effective in the future. Let's look at some of the strategies and developments which may be influential and claims which have been made:

1. Mainline CAI can cost less than $1.00/SCH if used as replacement rather than addition (Bunderson, 1970);

2. If institutions put a value on student time, CAI would become competitive (Judd, 1971);

3. A school system can share computer costs, e.g., administration, CAI, continuing education, adult education, neighborhood small businesses (Singh & Morgan, 1971);

4. Economy of scale can be reached through manipulation of number of terminals and/or average usage (Kopstein & Seidel, 1968);

5. Mass distribution of software can spread development cost (Singh & Morgan, 1971);

6. Multiple use of programs could become just as logical as multiple use of texts (Kopstein & Seidel, 1968);

7. Course development costs decrease as authors obtain experience with CAI (Bunderson, 1972);

8. Software development as part of theses and dissertations is a source of cost reduction (Bunderson, 1972);

9. With stable content areas, number of students (for assigning development cost, etc.) can be spread over several years (Civil Service Commission, 1971);

10. Superimposition of CAI on a computer installed for other purposes reduces the cost of CAI (Watson, 1972);

11. Costs can be reduced if terminal use is figured at more than a one-to-one ratio (OKey & Majers, 1975);

12. Standardization of format (language) would promote transfer of material (Butman, 1973);

13. A language exists (hypertutor) which is capable of transferring courseware between PLATO and other CAI systems (Schuyler, 1975);

14. Costs are reduced after systems pass the developmental phase (Watson, 1972);

15. Networks and consortiums can spread costs (Allen, 1973);

16. PLATO and TICCIT have been designed with cost effectiveness as a goal (Eastwood & Ballard, 1975; Mitre Corporation, 1974);

17. Hardware costs have been declining (Allen, 1973).

Investment and Operating Costs for PLATO and TICCIT. One of the interesting problems in applying technological devices in education has been the utilization of hardware items that were originally designed for other purposes. The computer is a good example of this where initial computer applications either emphasized business applications (e.g., IBM) or scientific computing (e.g., Control Data Corporation). However, this is no longer true with the advent of PLATO-IV (Programmed Logic for Automatic Teaching Operations) and TICCIT (Time-shared, Interactive, Computer-Controlled Information Television). These are two computer-based instructional systems

designed explicitly for educational applications. The two systems differ a great deal in their technical characteristics and capabilities. For example, PLATO-IV is designed to serve 4,000 specially designed terminals which have dynamic graphics, are touch-sensitive, can project color slides, and have an audio capability. The system is designed to give close to instantaneous response to terminal users while other systems, not designed for educational applications, may delay for seconds and even minutes during heavy utilization. TICCIT, on the other hand, connects a small computer (maximum number of terminals is 128) to home television sets via cable systems. A TV set is used as a display device and can be converted into an interactive terminal by adding an inexpensive electronic component and a keyboard. TICCIT's display capabilities include the standard alphanumeric characters in color, audio messages, graphics and up to five minutes of moving color television.

The TICCIT system was designed for a specific market: the teaching of basic mathematics and English writing skills to students in community colleges. The courseware comes with the TICCIT system in contrast to PLATO-IV.

Although PLATO has been used to teach many subjects at all levels--elementary through college--obtaining courseware for it remains a problem because of a lack of resolution of copyright problems. However, this problem should be resolved in the near future. Courseware royalties for use of PLATO have been discussed as being anywhere from $.01 to $.05 per terminal hour. Courseware costs for TICCIT are not presently known by the authors of this report.

Costs for the two systems differ given the difference in size of the system configurations. Mitre Corporation (1974) states that a complete TICCIT system (computer plus 128 terminals) will cost approximately $450,000. (This should fall to $250,000 when mass production is begun.) They also advise purchase of about $20,000 worth of spare parts and another $20,000 per year for a computer systems engineer to run and maintain the system. Costs for cable transmission or other operating costs are not mentioned. The goal of the TICCIT system is to provide instruction at less than $1.00 per terminal hour (including hardware, equipment maintenance, and prorated courseware cost). For applications in the State of Florida, these cost figures would have to be multiplied by the number of community college campuses on which TICCIT systems would be located. Assuming one for each of the 28 community colleges, the total capital cost would be (assuming the $250,000 mass production price per system) $7,560,000 plus $560,000 per year for personnel to operate the systems. The reader should bear in mind that all that would be taught by TICCIT are basic mathematics and English to students at the high school and community college levels.

The PLATO-IV system is much larger and more complex. Cost figures quoted by Hansen et al. (1975) are $8,000,000 for a PLATO computer (Florida State University already has an operational PLATO-IV system so this can be considered a sunk cost); $5,500,000 for 850 terminals (this price will come down rapidly once mass production has begun). Although no figures will be reported here, maintenance costs for terminals are known to be quite high. The Computing Center at Florida State presently charges $225 per month for terminal port

charges to use the computer. Assuming a school year of nine months, annual port charges (a recurring cost) would be $1,721,250 for the 850 terminals. (This charge could well be reduced if the number of terminals were substantially increased beyond the 30 or so that are presently on the system.)

Communications costs for connecting terminals with the computer would be substantial. At present this is done with telephone lines. Assuming an average monthly rate of $100 per terminal for dedicated long distance lines around the state, this would amount to $765,000 per year for a nine month school year. The University of Illinois has been experimenting with microwave relay systems and reports that they can be less costly than telephone lines for local applications. Use of a communications satellite might also result in long term cost reductions. Royalties for use of courseware would have to be included as would design and programming costs for courseware which is desired but not available. According to its advocates, maximum use of such a PLATO system could result in an average per student cost of under $1.00 per hour. This also assumes that there is sufficient courseware to achieve the required level of utilization. It is doubtful whether there is at present enough courseware to meet this assumption.

Experience at the University of Illinois indicates that programming one hour of instruction on PLATO can consume anywhere from 50-250 hours of courseware author time. Assuming 15 minutes of PLATO instruction per day in a given subject such as mathematics, programming this amount of instruction for a school year of 180 days would

require from 2,250 - 11,250 manhours of courseware programming time. At $8.00/hour, this would equal a programming cost from as low as $18,000 to a high of $90,000 to prepare one school year's worth of instruction for one subject at one grade level. These figures would have to be multiplied by the number of grade levels and subject areas to estimate total programming cost. However, it may well be that it is not necessary to use the computer to teach one lesson per day. It might be more cost-effective to use the computer for remedial work in a few select areas thereby reducing the amount of programming required.

The second type of computer-based education for consideration is computer managed instruction. CMI has been characterized as the middle ground between administrative use of the computer (e.g., data processing) and instructional presentation of CAI (Mitzel, 1974). Because the computer has been welcomed as an administrative tool, some hypothesize that CMI may be welcomed more readily for its administrative function capabilities (Kincaid et al., 1974).

Applications of CMI. An analysis of the CMI applications reviewed shows that the educational level found most frequently is post-secondary (Dunn, 1976; Gallagher, 1970; Hansen, Dick, & Lippert, 1968; Motley, 1972). However, CMI systems were also found at other levels: elementary (Allen, 1973), middle school (Durall, 1972), secondary (Eisele, 1971), and military (Hansen, Ross, Bowman, & Thurmond, 1975).

A conference on CMI (Mitzel, 1974) included discussion of 27 CMI systems. Target audiences were indicated for each system. CMI

applications tabulated by level were as follows: elementary, 3; middle school, 3; secondary, 6; postsecondary, 12; military, 4; other adult, 1. (The total is greater than 27 because some of the CMI systems serve learners at more than one educational level.) In addition, one system was labelled as for any instructional enterprise.

CMI appears to have potential in a wide variety of content areas. For example, applications were found for the humanities, natural sciences, social sciences, medical areas, education, etc. The learning outcomes involved were information and intellectual skills.

Effectiveness of CMI. The preceding discussion indicated diversity in CMI applications. It is important to determine the effectiveness of these systems and their applications.

The data on effectiveness are favorable. The results show CMI to be at least as effective as traditional instruction (TI) (Dick & Gallagher, 1971; Durall, 1972; Motley, 1972). Although very few of the system decriptions for the conference on CMI (Mitzel, 1974) included information on effectiveness; those which did report such results indicated no significant difference between CMI and TI.

Reduction in Time. In addition to achievement data, effects of CMI on time for learning have been investigated (Dunn, 1976; Motley, 1972). Generally, CMI has been shown to be effective in reducing time for learning (Dick, 1969; Mitzel, 1974).

Hansen et al. (1975) reported setting a goal to achieve a 30% time reduction for a CMI application for the U. S. Navy. In practice, they found reductions ranging from 35-45%. In a system in which CMI testing was used as a contingency rather than for grading purposes,

there was no significant difference in student study hours per week between the treatment and control groups (Anderson et al., 1975).

Student Attrition. Some CMI systems--postsecondary and military--have also compiled student attrition data. For example, Hansen et al. (1975) had a system goal to reduce attrition. Results indicated a reduction in attrition rate ranging from 4-11%.

Attitude Toward CMI. There were eleven studies which indicated that attitude measures have been used. Three of these did not provide details on the results of analysis for attitudes. One study (Eisele, 1971) found no significant difference in attitude. However, other studies reported favorable student reactions (Durall, 1972; Hagerty, 1970; Hansen, 1973). Hansen et al. (1975) reported favorable attitudes for both instructor and students. Hansen, Hedl, and O'Neil (1971) attributed favorable attitudes to the nonthreatening nature of the interaction.

The CAISMS studies (Anderson et al., 1974, 1975) also report attitude data regarding CMI. They found a generally favorable attitude toward CMI applications. However, student attitude toward computer time delays was negative. They indicated that improved attitude was more apparent with students assigned to large class sections.

Costs of CMI. The discussion of CMI has been encouraging regarding generalizability, effectiveness, and attitude. Another important area is the cost of CMI systems.

Two phases of costs are generally reported for CMI systems: (1) research and development, and (2) operating costs. A third area which is critical, but not frequently discussed, is (3) capital

equipment costs. Each will be discussed in turn.

Research and Development Costs. Research and development includes costs for both CMI system software and for courseware (albeit off-line) for the specific courses to be used on the system. Unfortunately, there is no uniform practice (process or products) for reporting these kinds of cost data. This situation could be at least partially corrected if the cost model for CMI which the federal government released in 1973 would be adopted as a standard (Rogers & Weinstein, 1974).

The problem of comparing or analyzing costs with the current situation can be seen by reviewing present variations: reporting cost/SCH without describing the computation formula (Durall, 1972); reporting total cost (Dick & Gallagher, 1971); itemizing costs (Dunn, 1976; Hagerty, 1970); itemizing hours and costs (Rogers and Weinstein, 1974). Often, the reader must decide whether costs refer to course development or computer systems software development.

This distinction is important. Course development or instructional design is predominately unique for a specific course offering. In contrast, system development consists of many elements which are transferable (Hauge, 1976). Developmental costs are expensive (Morgan, 1969). The idea that some developmental costs are nonrecurring is critical to analysis of costs for an expanding or expandable CMI system (Middleton, Papetti, & Micheli, 1974).

Costs for developing a large scale CMI system for the U. S. Navy are reported by Hansen et al. (1975). This CMI system is to have nearly 17,000 students participating on a daily basis by 1980.

There will be approximately 20 different courses being managed by the system. The CMI system encodes test scores and prescribes the next lesson for each individual. The majority of the learning materials are off-line, i.e., presented either by print, audiovisual, or human means. The cost figure to develop the "language/system" cited by Hansen et al. is 5 manyears at $40,000 per year for a total of $200,000.

Oosterhof at the Florida State University is presently developing a CMI system for use in postsecondary education. This system is designed to be a local application in contrast to the Navy CMI system which is nation-wide. Design of computer software and testing center procedures to administer individualized tests have been estimated to cost approximately $80,000 over a time period of 18 months. When the system is operational, it is estimated that it will cost approximately $2,500 to bring up a course on the CMI system. However, in order for course data to be ready for coding into the computer, another $2,500 per course is required to develop instructional objectives, which serve as the basis of instructional management, and to prepare a large test item pool referenced to these objectives. Preparing objectives and test items is usually a responsibility of a member of the teaching faculty. Small additional costs will be incurred whenever the objectives and test items are revised or updated.

Operating Costs. The issue of nonuniform reporting practices is also a factor in analysis of operating costs. Some report figures for a total course (Hagerty, 1970; Hansen, Dick, & Lippert, 1968). Others are interested primarily in costing the elements of the course directly related to the management system (Dunn, 1976; Hauge, 1976).

There are some encouraging results for operational costs. Three studies found CMI less expensive to operate than traditional instruction (Dick & Gallagher, 1971; Hagerty, 1970; Morgan, 1969). Each of these studies was in postsecondary education and involved reallocation of faculty time. Durall (1972) projected that CMI would become cost effective in the public schools by 1980. His estimated operating cost was $.78/SCH based on 70 students. Hooper (1974) also claims that CMI has a potential for cost effectiveness.

The total cost of CMI depends on whether the application is terminal-oriented or paper-document-oriented. Terminal-oriented applications require students to be tested on-line via a computer terminal. Costs involved in procuring and operating enough terminals to serve a target learner population could be large if the number of students to be served is large. For off-line applications of CMI, students record answers to test items on mark-sense answer sheets which are then fed into the computer by an optical scanning device. In this way, CMI data can be collected and input made either on an individual or group basis. Operating costs for such a system would include the cost of answer sheets and an unskilled operator who could be paid on an hourly basis or be an unpaid volunteer. Off-line applications of CMI have the advantage of reduced costs for terminals and for telephone line charges to connect them with the computer.

Capital Equipment Costs. In CMI applications, the computer functions as an information storage and retrieval device. Computers designed for administrative data processing can be used to support CMI applications. Therefore, school districts with time-sharing

data processing computers already possess one key item of equipment. Data processing computers which can operate only in batch mode could also be used for CMI applications. However, batch mode applications would not be as efficient as time-sharing systems in providing prescriptive feedback to learners. Hansen et al. (1975) quote a price of $2.5 million for the computer required to support the Navy's large scale CMI application. Multiplex equipment required to interface terminals with the computer would add another $300,000. CMI terminals for the Navy CMI system comprise an OpScan document reader and a keyboard printer which, together, cost approximately $9,000 per learning center. In his development work at Florida State University, Oosterhof presently estimates the cost of a CMI terminal similar to the Navy's as being around $13,500 per learning center or school site.

Programmed Instruction

Fourteen documents concerning the effectiveness and/or costs of programmed instruction were reviewed. Two of these are surveys of the available literature on programmed instruction (PI) which summarize over 325 studies comparing the effects of PI and traditional instruction (Jamison et al., 1974; Nash et al., 1971). They provide thorough coverage of studies that have been conducted at all grade levels in the public schools as well as in military and business settings.

The following conclusions are consistently reported throughout the literature:

- There is no overall significant difference between programmed and traditional instruction in terms of student achievement (Jamison et al., 1974; Nash et al., 1971; Johnson, 1970; Scanlon & Weinberger, 1973; Magange & Dar Es Salaam, 1974).

- The time required for attaining specific educational goals in traditional instruction can be reduced through the use of programmed instruction (Jamison et al., 1974; Nash et al., 1971; Johnson, 1970).

- Programmed instruction is as effective as traditional instruction in facilitating learning in all domains--attitudes, motor skills, intellectual skills, and information (Jamison et al., 1974; Nash et al., 1971; Johnson, 1970; Scanlon & Weinberger, 1973).

In addition to these general conclusions, there are specific conclusions found in isolated studies which are worth considering. For example, Magange and Dar Es Salaam (1974) found in their study of a group of Tanzanian adults that the combined use of PI and traditional instruction produced significantly higher student achievement than the use of traditional instruction alone. In terms of effectiveness this is quite useful; however, if PI is used as an "add-on" to traditional teacher-based modes, the likelihood of cost savings is reduced.

Scanlon and Weinberger (1973) reported results of a case study on the use of Individually Prescribed Instruction (IPI) in six U. S. elementary schools from 1968-73. IPI is an indivdualized instructional system using PI as its main (but not sole) form of delivery. The teacher is identified as a necessary component of the system to formatively evaluate individual student progress and to prescribe instruction on the basis of diagnostic test results. Therefore, this application of IPI was employed as an "add-on" to the traditional teacher-based system of instruction and resulted in an increase in instructional costs. Scanlon and Weinberger reported the following results for this IPI implementation:

- There was no significant difference between IPI and nonIPI students in achievement on standardized tests in mathematics and spelling. But IPI students scored slightly higher than nonIPI students on standardized reading tests.

- IPI students scored significantly higher than nonIPI students on tests of creativity, self-concept, and attitude toward school.

- Questionnaires administered systematically to IPI and nonIPI parents across schools indicated that IPI pupils were more highly motivated, self-directed, and independent than nonIPI students.

- Attitudes of IPI and nonIPI teachers were compared using a semantic differential measure. There were no significant differences between the two groups in perceptions of teaching roles, teacher/pupil relationships, or general attitudes towards students. However, IPI teachers had more favorable responses than the control group teachers toward (a) pupil's independence and self-direction, and (b) the value and productivity of the teacher aide.

These results were found across a large heterogeneous elementary school population.

Public schools in Dade County, Florida, have also tested applications of PI in mathematics and reading in grades 2-6. They describe their application as a systems approach to instruction based on diagnosis and learning prescriptions. In addition to developing programmed materials of their own, the Dade County schools have also tested materials published by others, e.g., the Wisconsin Reading System and the Individualized Mathematics System published by Ginn and Company. These instructional systems have required the use of teacher aides who have been paid by both federal and local funds.

In a report released by the Dade County Schools (Department of Planning and Evaluation, 1976), the following observations were made:

- Present results show that the systems approaches are, in general, comparable in achievement effects to those produced by conventional teaching methods.
- Teacher attitudes are favorable toward both the theory and the actual practice of these applications of programmed instruction based on a systems approach.
- Students of teachers with negative attitudes toward the teaching systems performed as well as students of teachers with positive attitudes toward the teaching systems.
- Provision of teacher aides produced no visible effect on Dade systems students. (Given this surprising result, the evaluators raised questions as to whether the aides had been properly trained to work with the learning sytems.)

Nash et al. (1971) make a distinction between "practical" and "statistical" significance in their interpretation and summary of over 100 studies on the effects of PI. They point out that a difference between two applications can be considered "statistically significant" if it is at the .05 level of confidence for a given number of subjects. But when it is actually implemented with a larger number of subjects, there may be only a 3-4% difference in outcomes between the two--a difference which may not warrant the problems and costs of adoption. In an effort to increase the utility of their intepretations of the literature, Nash et al. defined "practical significance" as a minimum difference of 10% between applications.

With this standard in mind, they found no "practically significant" differences between traditional instruction and PI in overall facilitation of immediate learning or retention. But they did find that PI was more effective for high and low ability groups than for average groups--for immediate learning, not retention.

And, in a strong response to the efficiency question, they found that PI almost always reduces training time by a "practically signi-

ficant" average of 33%. In addition, they suggested that this apparent time reduction may be a result of the self-pacing capabilities of PI in contrast to the fixed time spans associated with most traditional instruction, rather than some inherent substantive differences between the two.

Costs of Programmed Instruction. The potential cost savings in using teacherless multi-media programmed instruction were demonstrated by the Army through implementation of the Training Extension Course (TEC) (Temkin, 1975). Inasmuch as the initial development costs of multi-media programmed materials were high, the crucial factors in attainment of significant overall savings were: (1) replacement of teachers thus eliminating their salaries as costs of instruction; and (2) expanded utilization of the instructional materials. One hundred TEC lessons were provided per year to each of 533 men per battalion for 1064 battalions. With the implementation of the TEC program, the Army realized a savings of about $8 million per year in comparison with the cost of conventional teacher-based instruction.

For the six schools in the Scanlon and Weinberger (1973) case study, the "add-on" costs of IPI ranged from $20.16 to $216.45 per pupil per year five years after initial implementation. The large variation in initial "add-on" costs across schools was attributable to variations in staff additions for the IPI program. By the 5th year of the project, cost reductions of 8-35% were achieved mainly through reduction in costs of materials and training and, in part, through a slight reduction in staffing made possible by improved personnel management techniques.

Costs cited in the Dade County report mentioned above are similar to the IPI experience. At the present time, approximately 60% of the pupils in grades 2-6 are involved in either a systems reading or a systems math class. As of May, 1975, about 38% of the pupils were receiving instruction in both reading and math via the systems materials. In addition to PI materials, the county employed 300 aides for a total annual cost of $1.9 million. Each aide was assigned to give assistance to up to 12 classes.

Using average materials costs per pupil reported in the Dade County study, we attempted to calculate "add-on" costs required to implement the individualized teaching systems in reading and math in grades 2-6. Depending on which particular set of materials was used, we estimated that the average per pupil cost per year could range from $18.77 to $23.58 for reading and from $18.83 to $21.89 for math. These figures include teacher aide costs averaged over classes plus average cost per pupil for materials. Assuming that a teacher aide could effectively support instruction in both reading and math in each of 12 classes, we calculated an average "add-on" cost ranging from $19.70 to $27.34, again depending on which sets of learning materials were used. Given a student population of 90,000 students, we calculated that recurring annual expenses for adopting these individualized math and reading systems would be $1.9 million for teacher aides plus $500,000 for learning materials.

It is conceivable that either the IPI or the Dade systems programs could be implemented as a substitute for teacher-based instruction and could be managed by nonprofessionals who were trained to evaluate

student progress and to write the required learning prescriptions. This is a possibility worth considering if cost reduction is a goal.

Estimates of the Cost Saving Potential of Technological Applications

Cost data presented in this section have documented component costs and total dollar expenditures that have been required to plan, install, and operate the various technological applications under review. However, these data do not tell us whether there are any cost savings involved if these applications are used to replace live teachers to any significant extent. Fortunately, Kincaid et al. (1974) have simulated an estimation of cost savings that could accrue if classroom teachers were replaced by technological applications.

Their simulation procedure was based on the following assumptions regarding the lifetime of basic components.

Component	Lifetime (in years)
Locally produced courseware	3
Commercially produced courseware	5
Equipment such as delivery trucks projectors, television receivers, videotape recorders, etc.	5
Initial planning	10
Initial teacher training	10
Installation costs	10
Most major equipment such as computers, production equipment, etc.	10
Buildings	25

Sensitivity analysis techniques were also used to examine the effects of three levels of intensity of use (i.e., 20 minutes per week, 20 minutes per day, or 60 minutes per day of media-based instruction) and four levels of extensity of application (i.e., school districts of size 10,000, 30,000, 150,000, or 600,000 students).

Results produced by this simulation procedure indicate that the costs of various technological applications fall into a general order regardless of the size of the environment or intensity of use. Going from most expensive to least expensive, the rank order is:

1. General purpose computer based systems
2. Specialized drill and practice computer systems
3. 16mm film
4. ITV
5. Sound-filmstrip
6. Programmed text

Given these results, it seems clear that the instructional media with the greatest cost reduction potential would be programmed texts, sound-filmstrips, and ITV. Although Kincaid et al. did not calculate costs for instructional radio, this medium would probably fall at a level close to but slightly greater than programmed texts. Now that the relative costs for these media are apparent, what is their actual cost saving potential? Again we turn to the work of Kincaid et al. to seek results bearing on this question.

Recognizing that it would be hazardous to attempt to estimate precise cost savings potential because of variations in local instructional personnel deployment and costs, Kincaid et al. chose to estimate

an upper bound for potential cost savings attributable to substituting media instruction for classroom teachers. They described assumptions underlying their estimation procedures as follows:

> An upper limit on potential cost savings within the bounds of present knowledge and oraganization can be evaluated if it is assumed that the technological system itself costs nothing and that no classroom personnel are required during its use. This means that the use of technology for an instructional task is assumed to reduce to zero the budgetary costs of that activity (p. 24).

One other assumption which had to be made dealt with the upper limit of media utilization for direct instruction. Based on experiences gained in school-based projects such as Washington County, Maryland, and Anaheim, California, Kincaid et al. established that technological applications would probably be used for less than 25 percent of total instructional time. This led to the conclusion that:

> . . . the upper limit of budgetary cost savings to be anticipated using forms of instructional technology now envisaged is from 10 percent to less than 25 percent of total instructional costs, even if the technology (including equipment, supplies, and furniture) is costless and requires no classroom personnel whatever . . . . We conclude that even by the most optimistic estimates cost savings from the use of technology would not be more than 11 percent of the total cost of elementary and secondary education, using any technology now envisaged and the highest levels of use that have been sustained in practice in developing countries. While not negligible, these savings do not represent the kinds of radical cost reductions that technology has attained in industrial applications (p. 26).

What cost savings have been observed in actual practice? As mentioned previously, there have been few, if any, projects whose aim has been to reduce costs or to increase productivity. However, Kincaid et al. do report that the Anaheim, California, ITV system produced a saving of about 3.0 percent of instructional costs.

By way of contrast, Cresap et al. (1971) estimate that application of systematic personnel redeployment procedures can reduce overall costs by up to 8.5 percent. In a similar vein, Curry and Sweeney (1973) estimate savings of 4.9 percent from more intensive use of staff and 4.7 percent from more intensive use of capital facilities; this was for a 45:15 plan instituted in Prince William County, Virginia. The total cost savings of 9.6 percent for this particular project is at the upper end of the cost saving range for a costless instructional technology. Moreover, this approach requires no capital investment beyond planning expenses.

After comparing the results of their cost analyses with cost savings estimated to accrue from more efficient use of resources, Kincaid et al. state:

> We are therefore forced to conclude that, for the kinds and levels of use of instructional technology with which researchers are to date familiar, the cost savings obtainable are not large, and at present are simply not as attractive as other, more immediate and less capital-intensive means of reducing costs, no matter how inexpensive the technology may be. The promise of technology in elementary and secondary education, within the confines of present knowledge and organization, lies not in directly substituting for classroom teachers, but in aiding their instructional activities. . . . The possibilities of significant cost savings, on the other hand, depend more on social policy decisions concerning the custodial functions of schools--the length of time students are required to spend there--than they do on technological variations within the school (p. 27).

At this point it is important to draw attention to the two faces of educational technology as we use it in this report. For without labeling them as such, the systematic approaches followed by Cresap et al. and by Curry and Sweeney are clearly examples of the problem solving and design side of educational technology.

Moreover, the basic assumption underlying the instructional media applications seems to be that the only problems requiring a solution are instructional in nature. But what would happen to costs and educational effectiveness if curriculum goals were changed, classroom management techniques were revised to permit larger pupil/teacher ratios, and instructional delivery procedures were redesigned to accommodate both new curriculum goals and management procedures? Unfortunately, there are few examples and very little data on costs and effectiveness for the total system design efforts that would be required to answer this question. An exception to this is the Korean Elementary/Middle School Project (Morgan & Chadwick, 1971). Although this project was conducted in a social environment different from the state of Florida, a description of the total system design process that was used should prove enlightening.

Morgan and Chadwick report that the first phase of the project was devoted to analyzing the social system in Korea. On the basis of this analysis it was concluded that the vocational schools were not adequately preparing learners to occupy required occupational roles. This seemed to be the result of a number of factors which included: inadequately conceptualized vocational goals; lack of responsiveness to societal needs on the part of curriculum planners and teachers; and lack of qualified staff and materials. In effect, the vocational schools were functioning as low grade academic institutions. The vocational schools were thus providing a second-rate general education at relatively high cost. Based on the analysis of

social, economic, and educational factors, a total design effort was initiated and resulted in:

- A restructuring of the entire curriculum which required the addition of vocational subjects and the deletion of academic or general courses
- An increase of pupil/teacher ratios from 55:1 to 75:1
- Sixty to 70 percent of all direct instruction was to be performed by ITV, radio, or programmed instructional materials
- Approximately 30 percent of the school day was to be teacher-directed with these classes having a pupil/teacher ratio no larger than 40:1.

The cost savings achieved by redesigning the school system were estimated to be approximately 23 percent. These savings were then reallocated to provide access to a significant segment of the learner population that had been previously denied a middle school education. At this point in time there is little evaluation data available because Korea is still in the process of implementing this educational reform.

The cost savings potential of educational technology is not well documented as yet. However, in the few known cases available to us, the cost savings potential of the problem solving and design side of educational technology appears to be greater than that which might be achieved by large scale applications of instructional media technology. It may well be that the largest cost savings could be achieved through a combination of problem solving, design, and instructional media applications as was done in the Korean project. In any case, the potential of educational technology (as process and as application) to address financial and productivity problems remains to be tested in American education.

Summary

Regarding the Effectiveness of Technological Applications. Four varieties of technological applications in education were reviewed. They included: instructional radio (IR); instructional television (ITV); computer-assisted instruction (CAI) and computer-managed instruction (CMI); and programmed instruction (PI). Literature which documents the results of these technological applications is extensive and leads us to conclude that:

- These applications have been used at all educational levels--from early elementary through adult and continuing education
- These applications have been used successfully in practically all subject matter areas
- Students learn effectively from all of these media, and relatively few studies indicate a significant difference which favors one medium over another--including comparisons with traditional instruction

Regarding Attitudes Toward these Applications. Student and teacher attitudes toward these media applications have been favorable for the most part although certain qualifications should be noted:

- Resistance among teachers has been aroused wherever and whenever ITV has been introduced
- Teachers and pupils are more favorable toward use of ITV in elementary school than in secondary school and college
- College students tend to prefer small discussion classes to ITV classes, and ITV classes to large lecture classes
- Attitudes toward CAI and CMI have been favorable except for the cost area--they are expensive to install
- Applications of PI at the elementary level have been received favorably by students, parents, and teachers

Regarding the Learning Efficiency of these Applications. Mass media and instructional delivery systems such as radio and television do not lend themselves well to learner pacing or learner control. Therefore, their potential for achieving reductions in learner time is much lower than for applications such as computer-assisted learning or programmed instruction. The latter two applications lend themselves extremely well to individualization and self-pacing. The literature review suggests that:

- Applications of CAI, CMI, and PI can result in significant time savings--up to 33% less learner time

Largest cost savings have been reported in military applications where time devoted to learning is directly associated with time taken away from other activities. Thus, time savings can result in actual dollar savings. Schooling in grades K-12 also has an opportunity cost but compulsory education laws obscure this in practice. A area of significant cost savings potential would be opened if schools could be removed from having to provide the custodial function which arises from compulsory education laws.

Regarding the Costs of Selected Technological Applications. Documentation of the costs involved in applications of media-based instruction is becoming more plentiful. Major cost categories for electronic media such as radio, television, and computers include:

- Planning and start up costs
- Programming costs including capital investment in production equipment and annual programming costs
- Transmission costs
- Reception costs

There appears to be a wide variety of methods for calculating unit

costs thus making it difficult to compare cost data from one project to another. Inasmuch as budgets for most schools are fixed, applications of hardware-based technology will require increasing pupil/teacher ratios in order to free funds to pay for capital outlay required for production, transmission, reception equipment, and programming costs. If capital funds for expenditures are not generated in this way, then expenditures for equipment and programming become incremental thereby precluding the possibility of cost reduction in any real or absolute sense. Projects which have documented cost data suggest that:

- High cost technological applications such as ITV, CAI, and CMI should last from 15-20 years in order to achieve unit costs equivalent to or lower than unit costs for traditional instruction

Shortcomings of Present Technological Applications. After conducting one of the most extensive reviews of the research literature on educational technology, Jamison et al. (1974) conclude that:

> Technology* has been more successful in providing an alternative to schools; successful examples here include the British Open University, the Bavarian Tellekolleg, and the Japanese NHK's Secondary School of the Air. Technology* has not yet proved that it can play an important role in American schools (p. 58).

These authors make two other observations worth noting:

- Applications of educational technology* in the United States have been primarily add-on inputs to enrich student experience
- There are few, if any, examples where applications of technology* have improved school system productivity

Jamison et al. also report that they were unable to find examples where the goal was to reduce costs or improve productivity. Most of the studies represent applications of media rather than total design

*Actually "technological applications" as used in this report.

efforts that would be required if productivity were to be increased in any significant way. Therefore, readers should bear in mind that the educational technology to which Jamison et al. are referring is primarily hardware-applications-based. Their conclusions fail to address or to acknowledge the problem solving and design capabilities inherent in the concept of educational technology as we use it in this report.

Regarding the Cost Saving Potential of Technological Applications. The upper limit of cost savings to be achieved through applications of hardware-based applications is estimated to be:

- No greater than 11 percent of the total cost of elementary and secondary school expenditures

In one of the few known cases of cost reduction:

- Cost savings of 3.0 percent were observed for an application of instructional television in Anaheim, California

More substantial savings have been achieved through application of the problem solving and design side of educational technology. The following cost reductions were estimated for an application of the 45:15 plan in Prince William County, Virginia:

- More intensive use of staff achieved savings of 4.9 percent
- More intensive use of capital facilities achieved savings of 4.7 percent

The Republic of Korea sought to redesign its elementary and middle school curriculum and instructional delivery system. This project is one of the few documented in the literature where the goal was to redesign the entire educational system at the given levels. The major outcome of this educational reform was that:

- Through increasing class sizes in conjunction with utilizing ITV, instructional radio, and programmed instruction, the Republic of Korea has projected a cost saving of approximately 23 percent.

Although the problem solving and design processes of educational technology seem to possess a great deal of potential for addressing financial and productivity problems, this potential remains to be tested in American education.

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